Current-induced wave modulations observed by a GPS wave buoy deployed near Kozu Island, Japan

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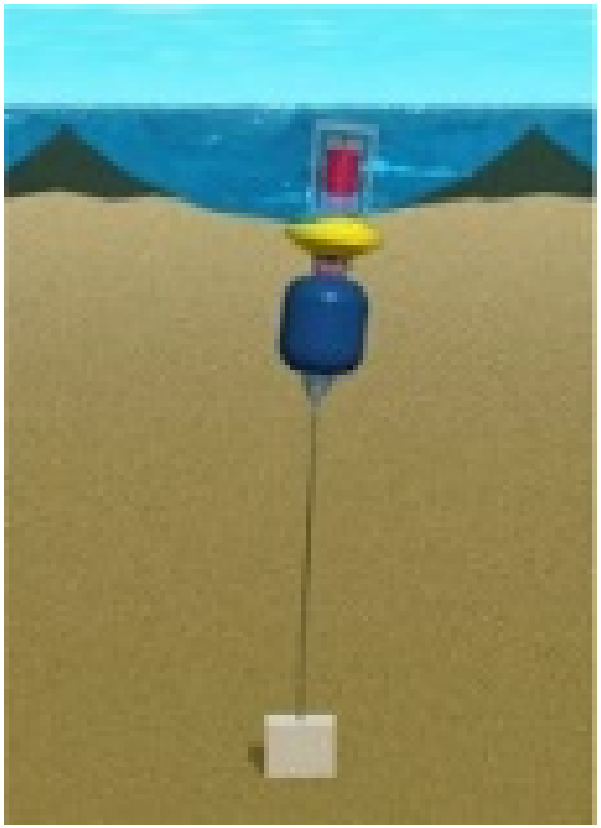
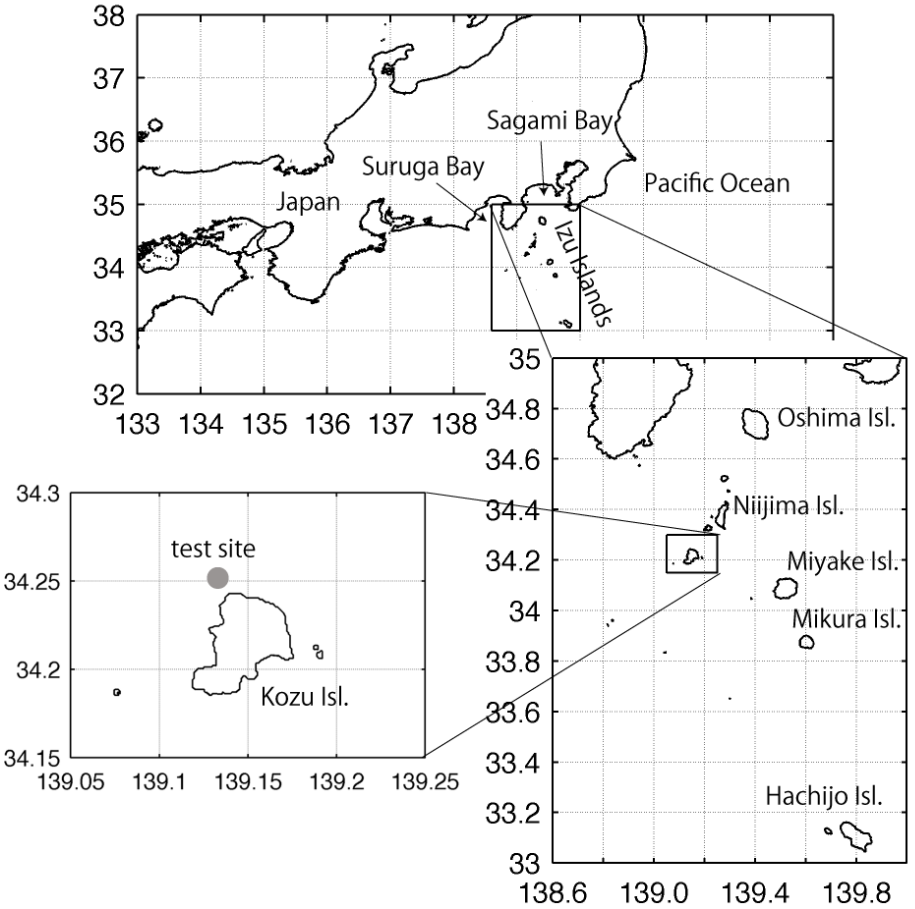
Outline

- Introduction
  - Background and Motivation
- Observation insturument
  - GPS wave buoy (moored and dirifting)
- Results of analysis on the observed data
  - Buoy trajectory, wave hight, wind etc.
- Results of numerical modeling
  - WWIII, simulation with and without currents
- Summery

Introduction

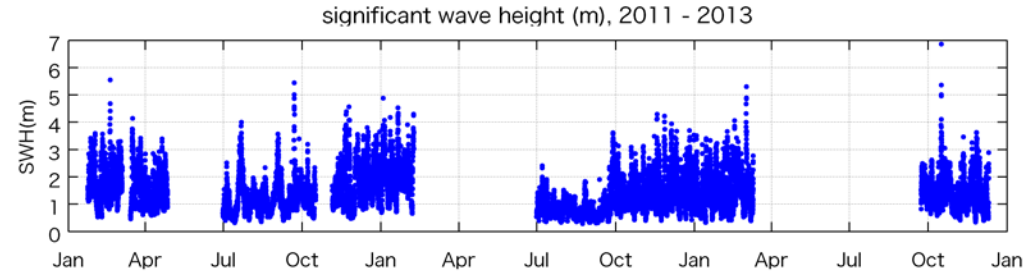
- Background
  - Wave Energy Converter Development Project
    - By Mitsui Engineering and Shipbuilding Company
    - Test site -> offshore Kozu Island

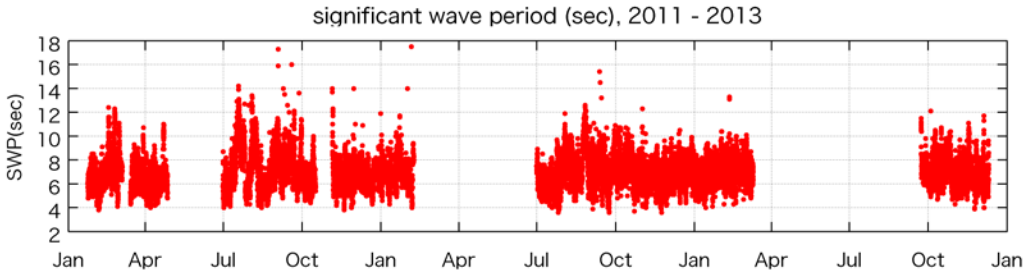


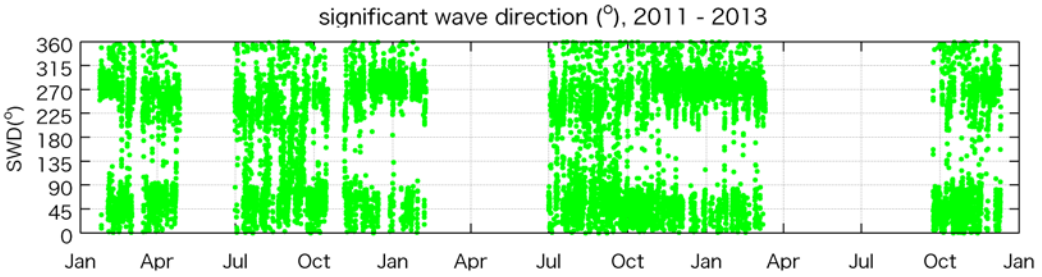


– Our Work

- Wave and current observations at the test site



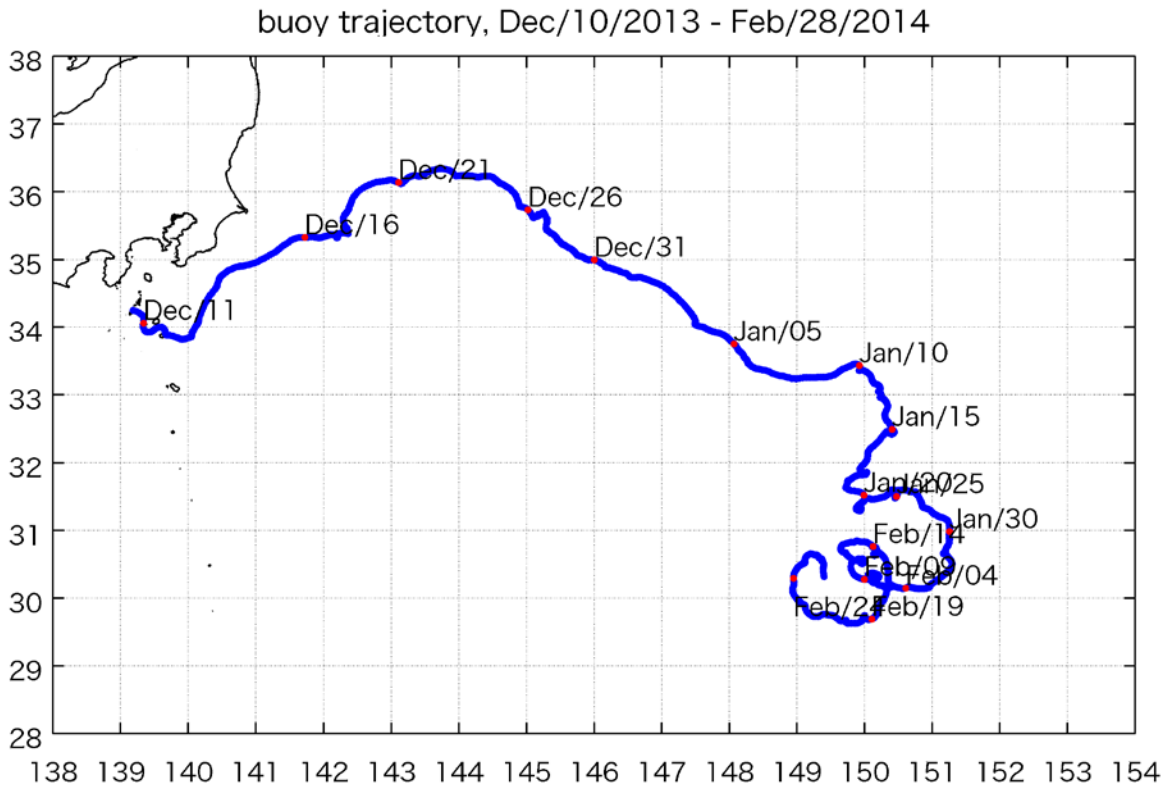




Topics related to the observation

- seasonal characteristics
- island shadow effect
- wave-current interaction
- model validation
- wave power estimation

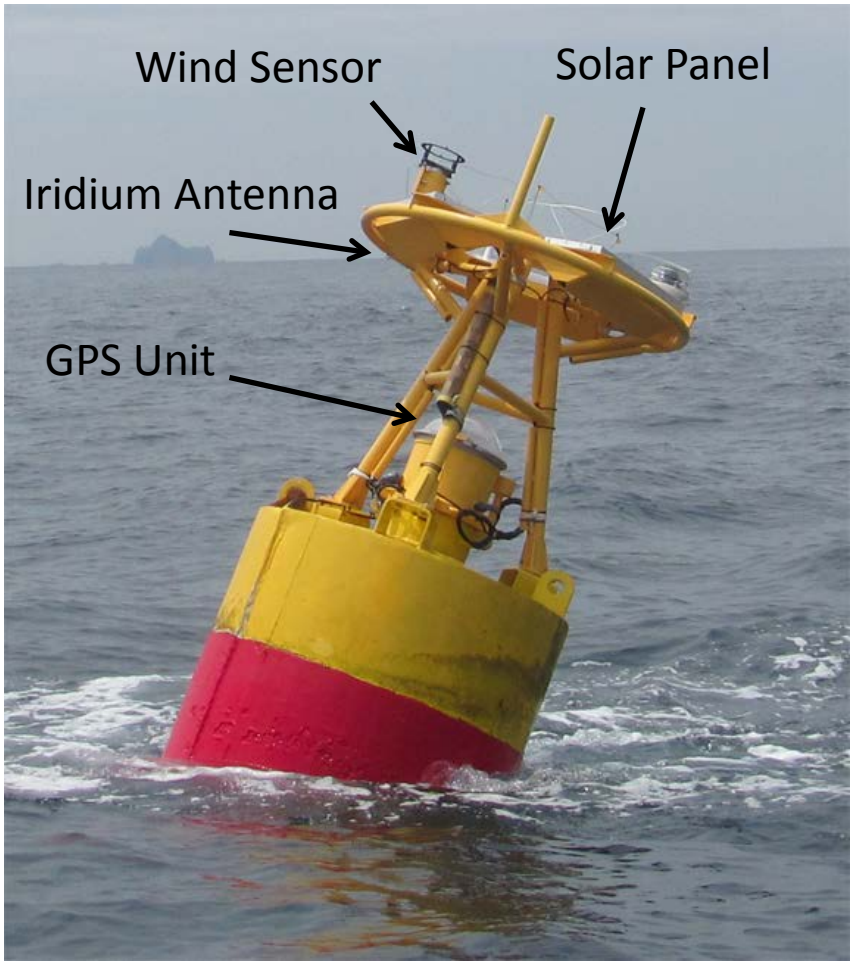
– Today's topic : Drifting event
  - 81days (Dec/10/2013 – Feb/28/2014), 2100km, 28cm/s
  - Waves around Kuroshio Extension region was observed
    – Wave modulations due to strong currents

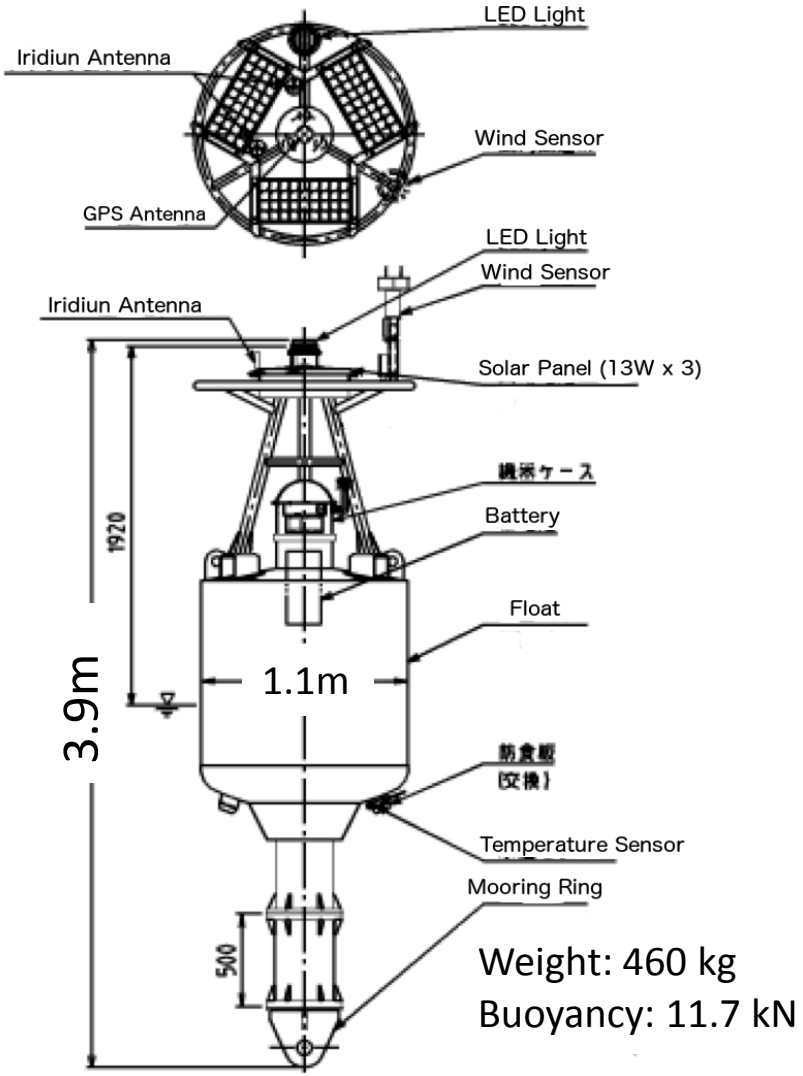


- Motivation
  - Getting Knowledge of offshore waves for Kozu project (and other works)
  - Model validation for NEDO potential project
    - *Nov/11, Progress on a 20-Year High-Resolution Wave Resource Assessment of Japan*
  - Making a description for future data release
    - Buoy trajectory
    - Wave characteristics and related weather condition
    - Wave – current interactions

Measurement Instrument

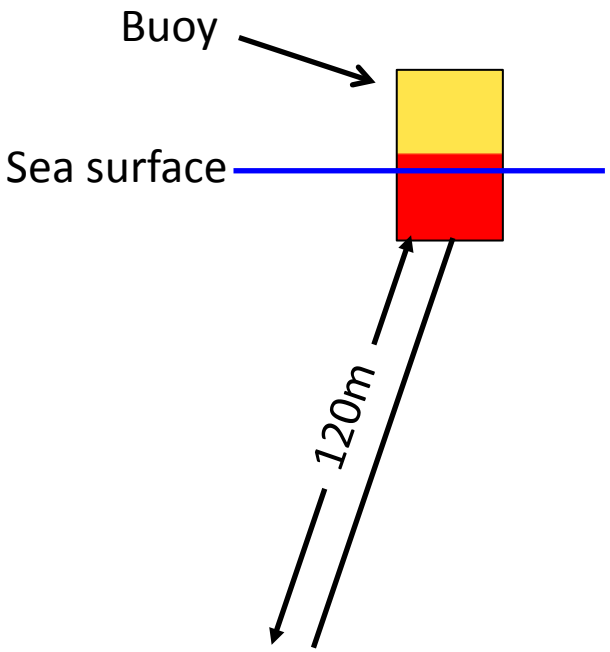
- GPS Wave buoy





Drifting condition

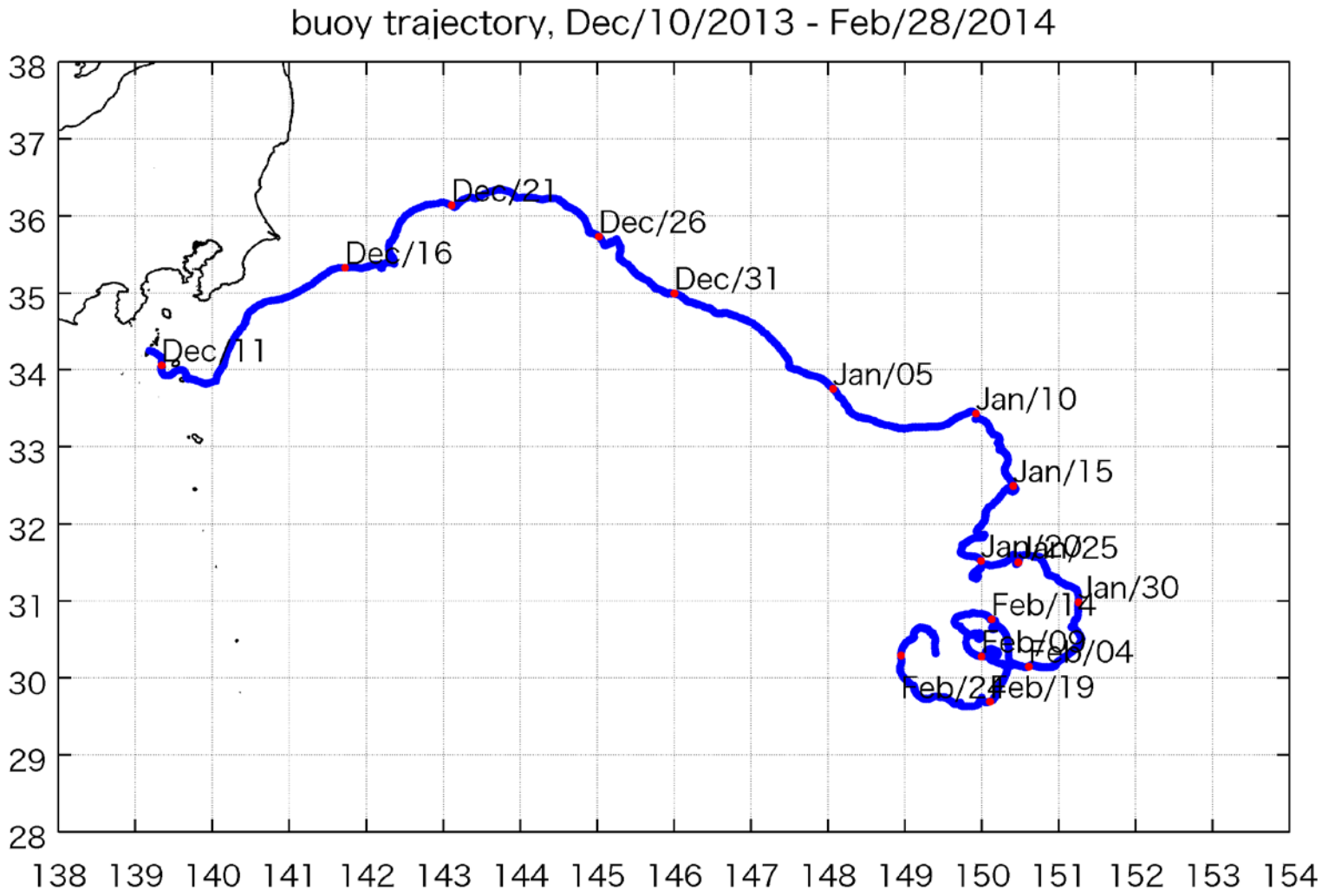
- The Buoy was drifted with 120 m rope.
  > stabilize the buoy motion



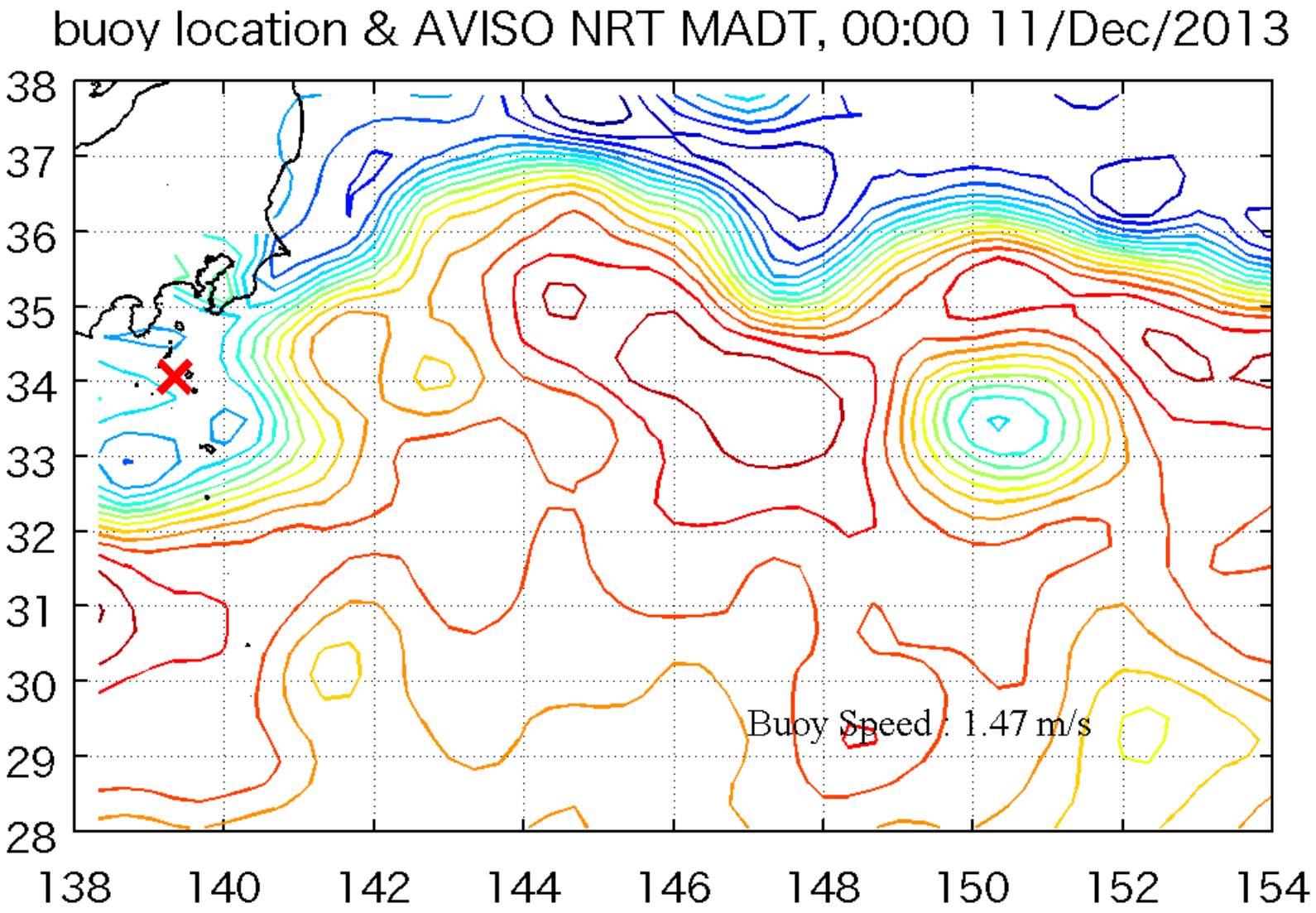
Picture of the rope

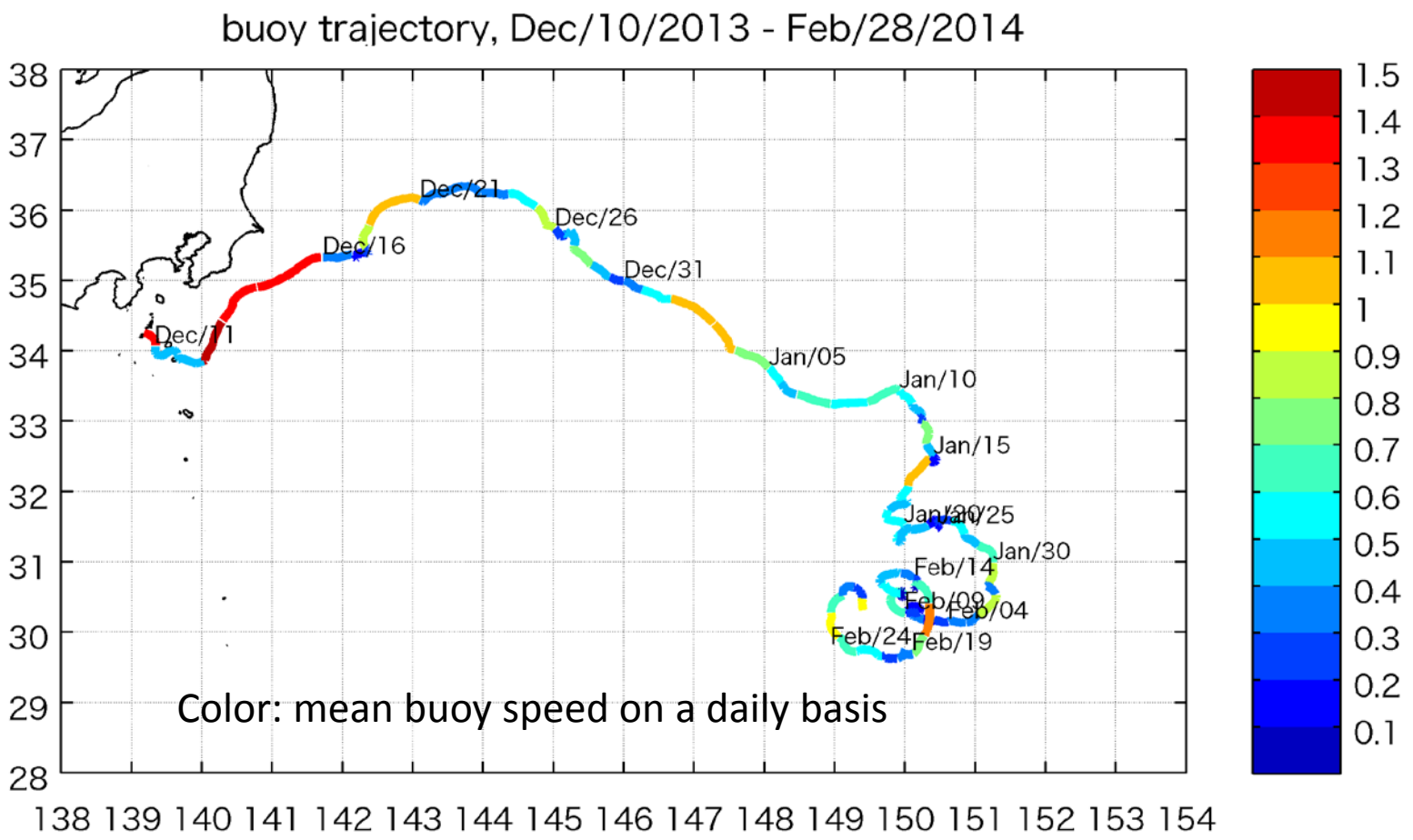
Analysis on the observed record

Buoy trajectory



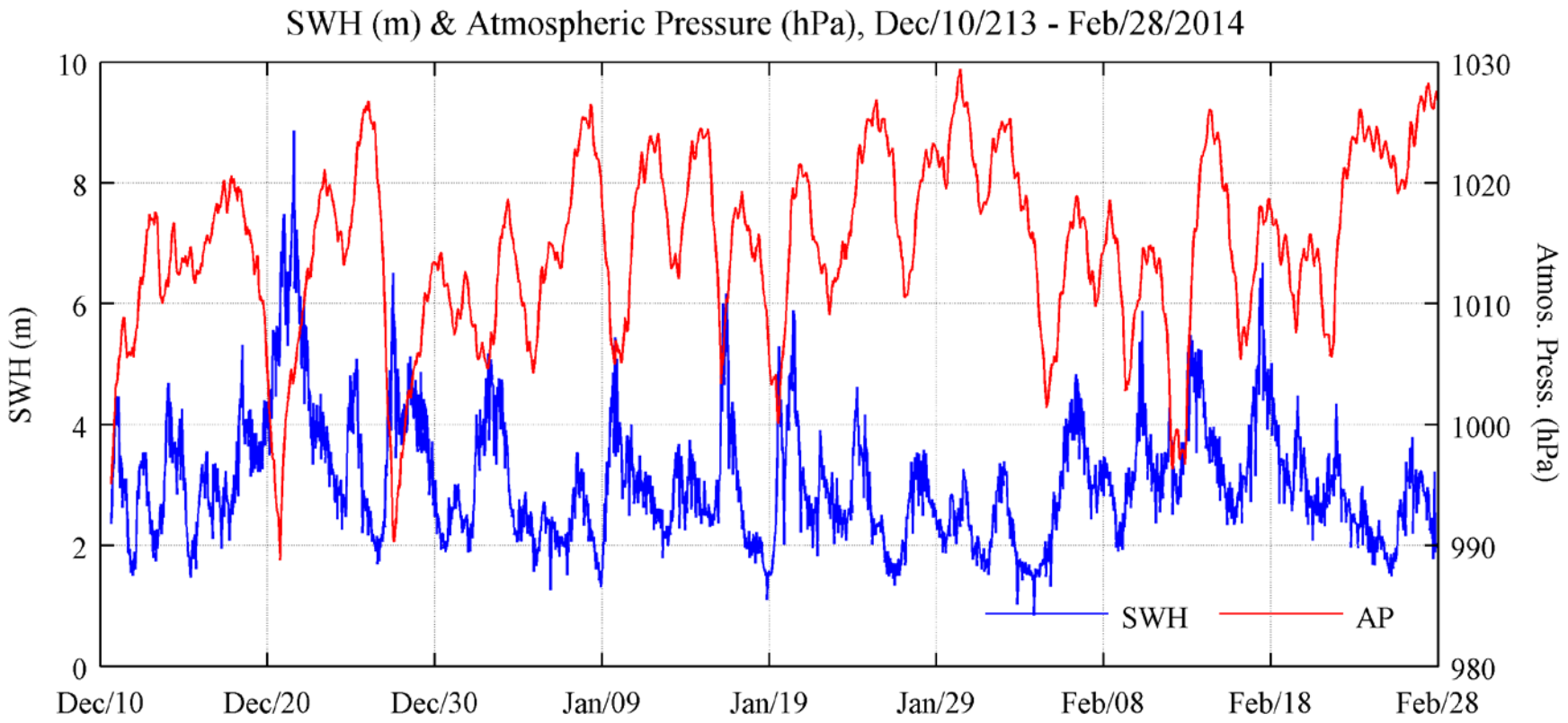
Animation: Bouy location and Sea Surface Height





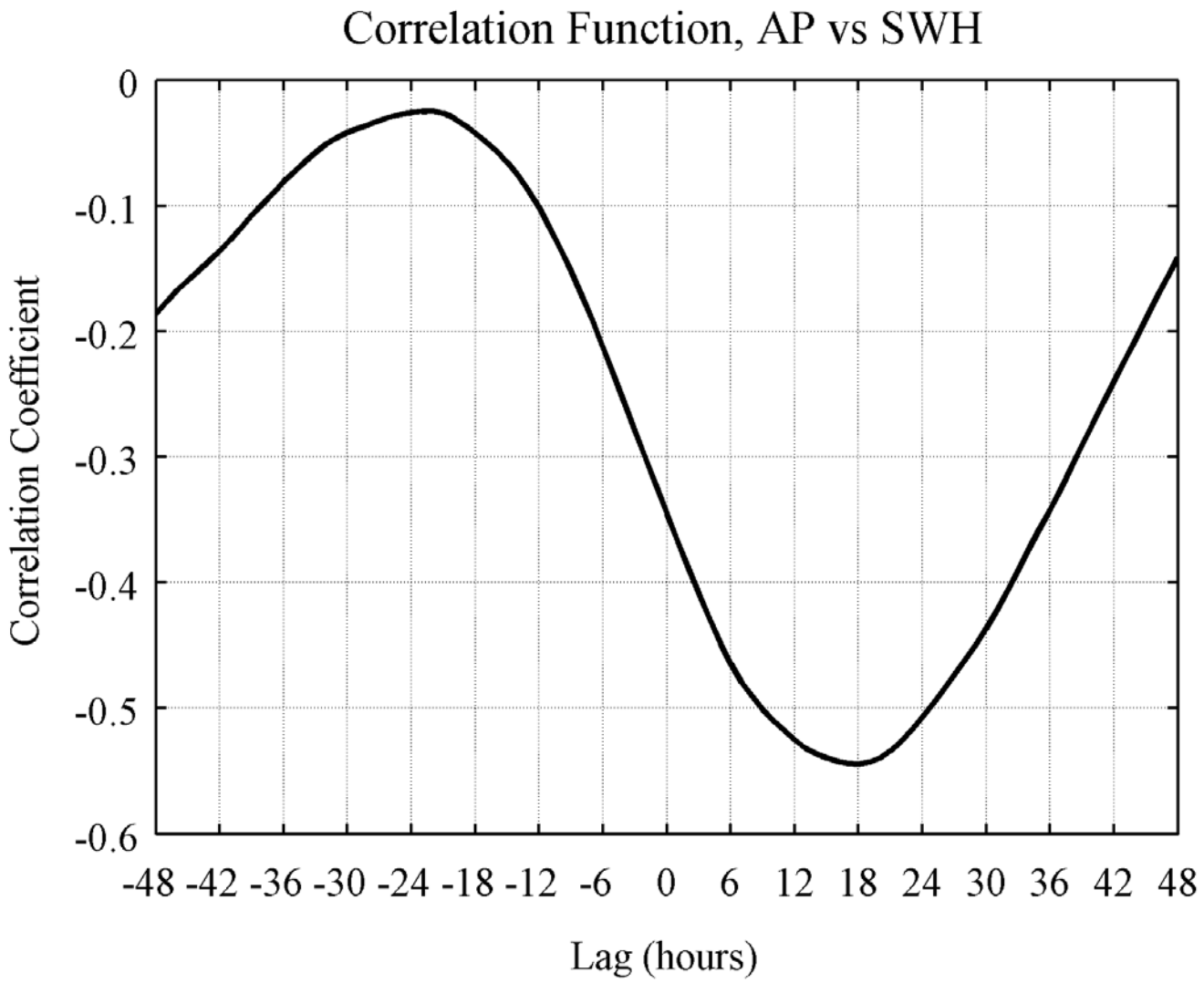
Period	Buoy Location	Estimated Forcing
Dec/10 – Dec/12	Inshore area of the Kuroshio	Tide, Wind
Dec/12 – Dec/16	Kuroshio Extension (near axis)	Kuroshio Extension, Wind
Dec/16 – Jan/10	Kuroshio Extension (southren edge)	Kuroshio Extension, Wind
Jan/10 – Feb/28	Southern Recirculaion of the KE	Eddies, Wind

Wave characteristics and related weather condition



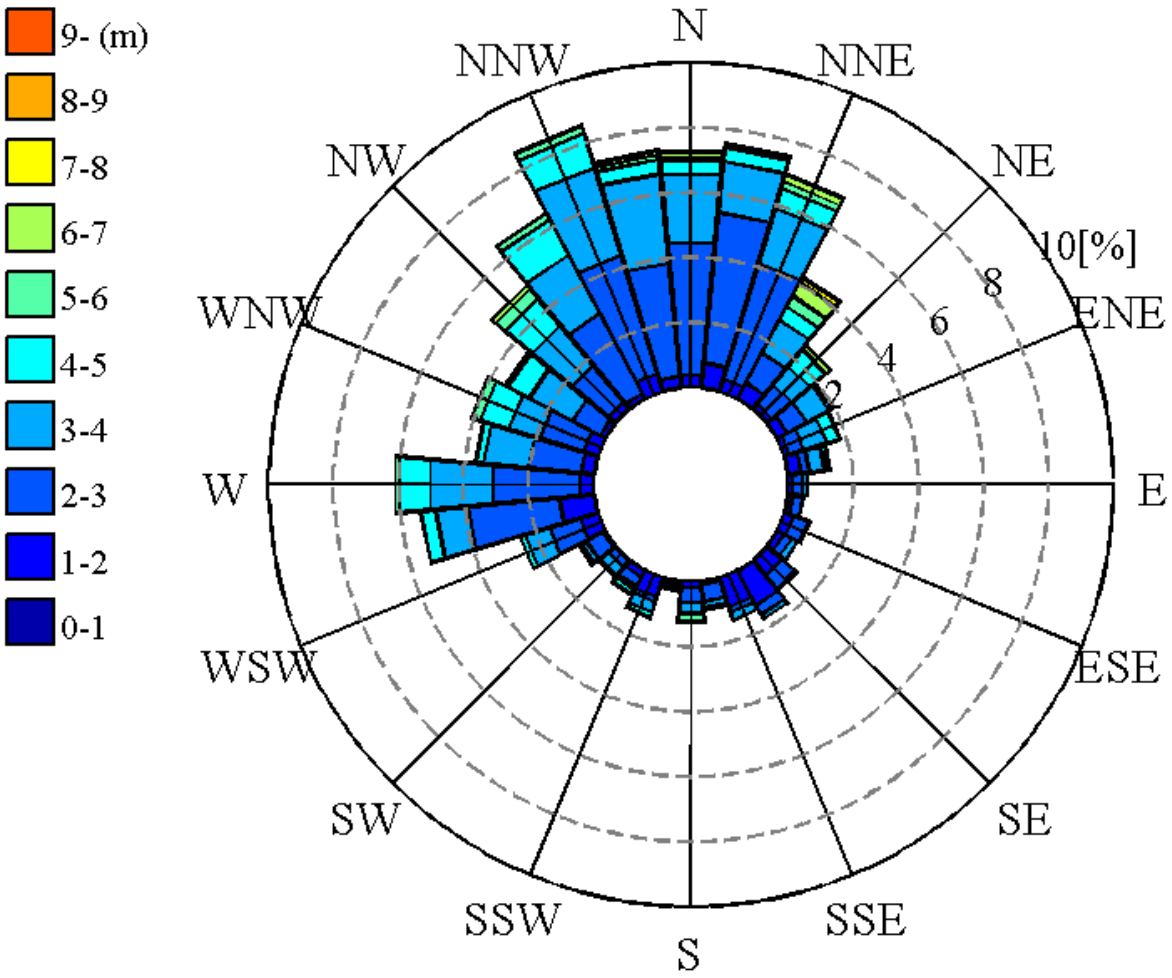
Time series of SWH (blue) and atmospheric pressure (red)

Wind data is not available due to sensor failure.
-> Atmosperic pressure data is important for understanding weather condition.



Correlation function between AP and SWH.
Positive lag means AP precedes SWH.

Pressure decrease happens 18 hours before increase of wave height.

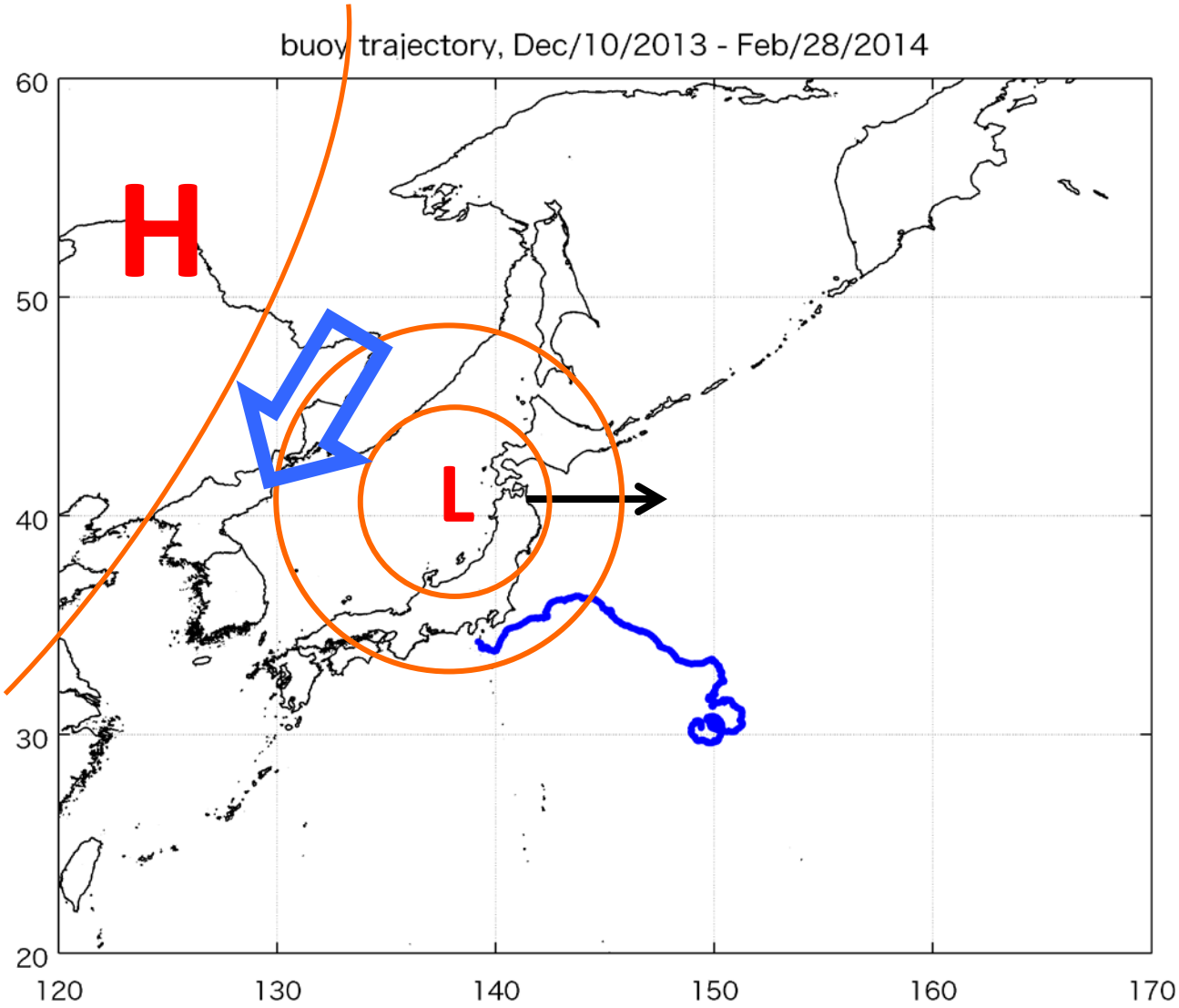


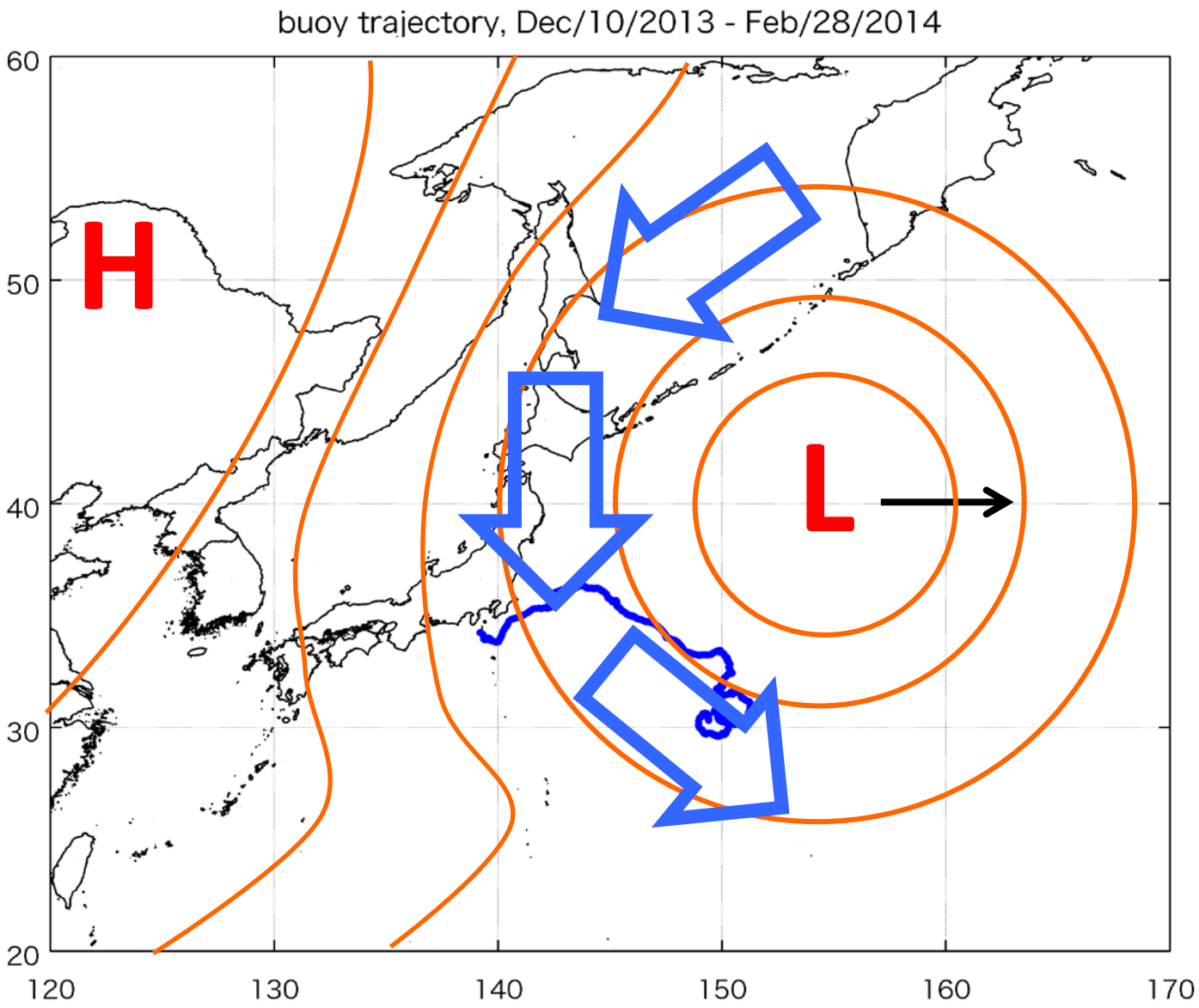
Wave climate
Color indicates SWH.

Northerly waves are dominnant.

Estimation of typical weather pattern

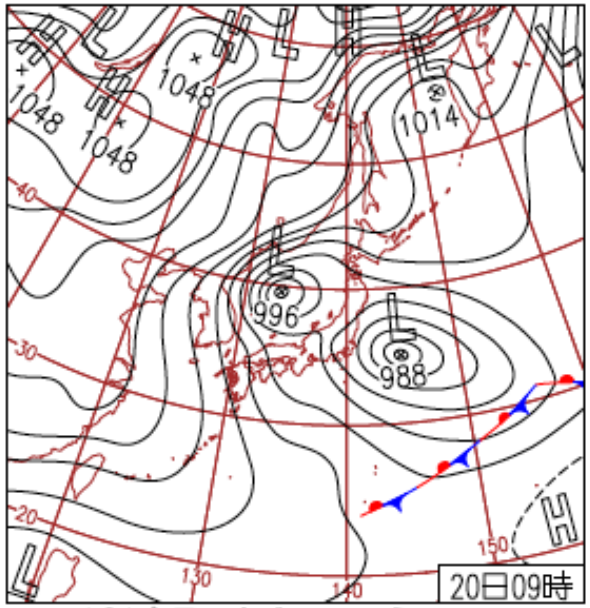
1. Pressure decrease precedes wave growth
2. Northerly waves dominate observed waves.





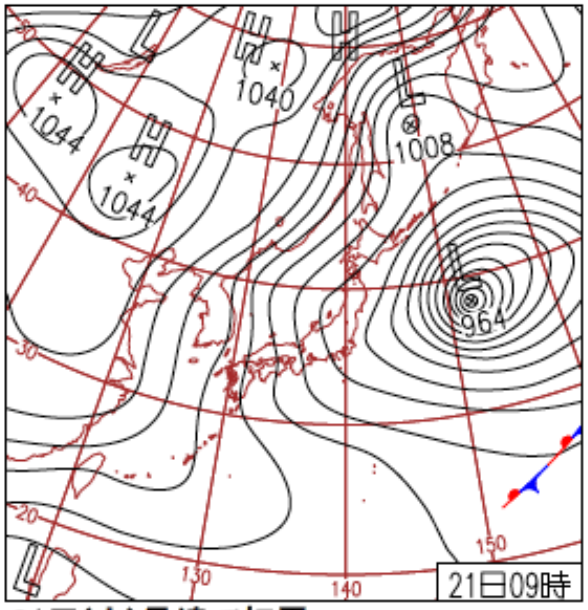
The low pressure becomes large and strong over the east of Japan.
Strong north wind -> High wave height.

Weather Chart by JMA

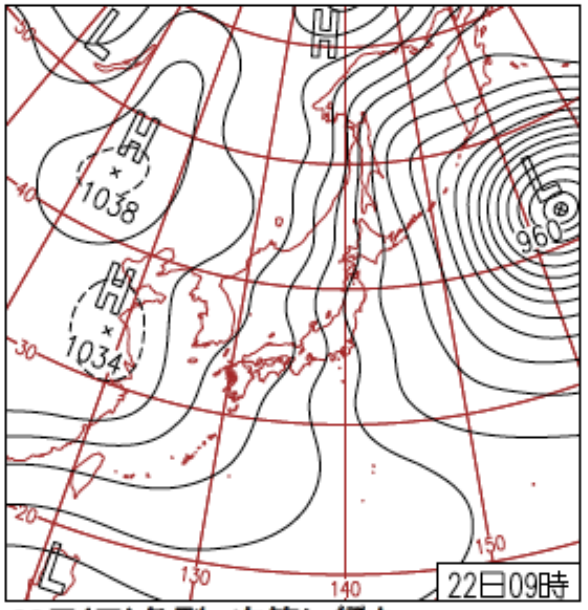


20日(金)鳥取・東京でひょう

上空に寒気
陸へ進んだ
囲で大気の
海側を中心
大瞬間風速



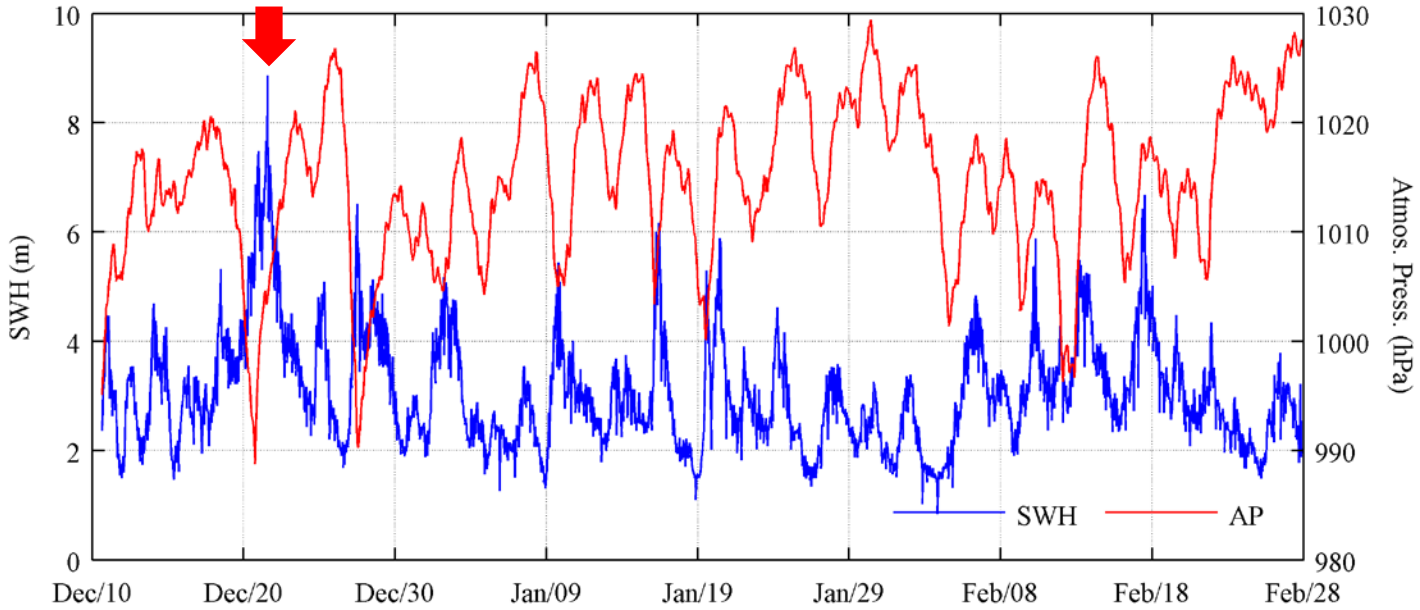
21日(土)長崎で初雪



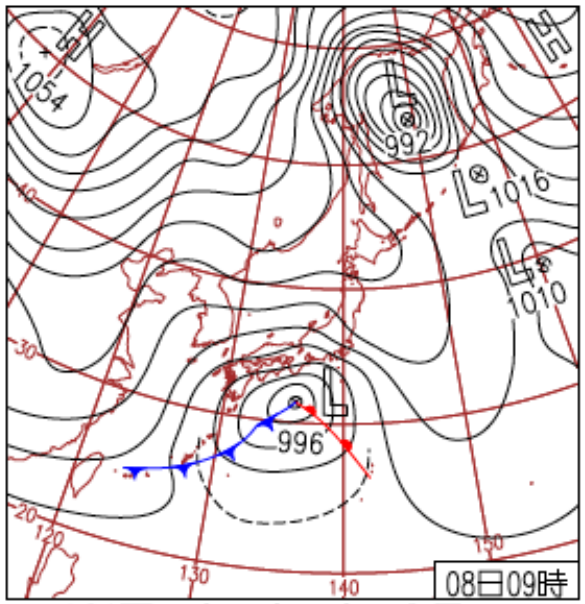
22日(日)冬型、次第に緩む

に去り、
本海側
では晴
氷と初

SWH (m) & Atmospheric Pressure (hPa), Dec/10/213 - Feb/28/2014

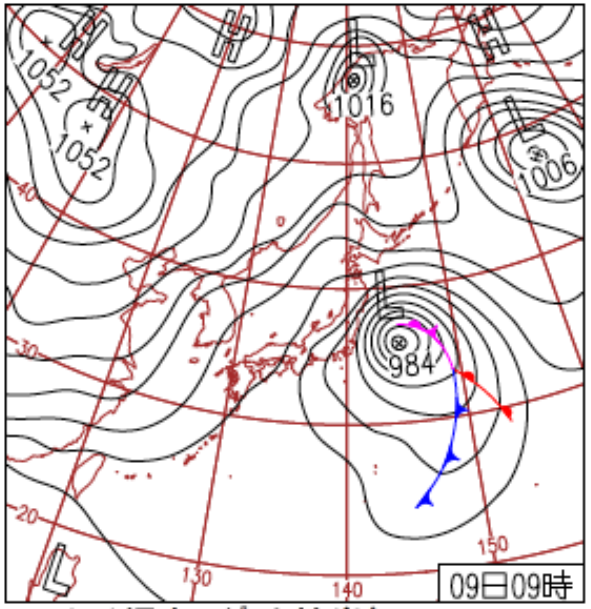


Weather Chart by JMA

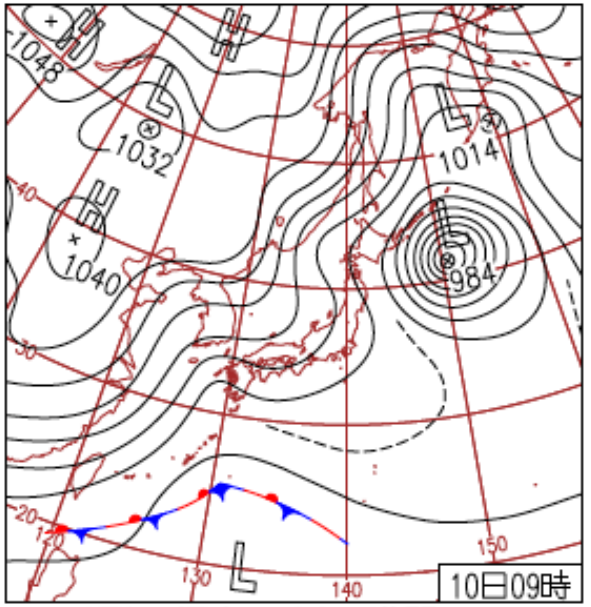


8日(土)西日本～東日本で大雪

南岸低気圧
関東～東北
中央区32c
葉県銚子
県で震度4

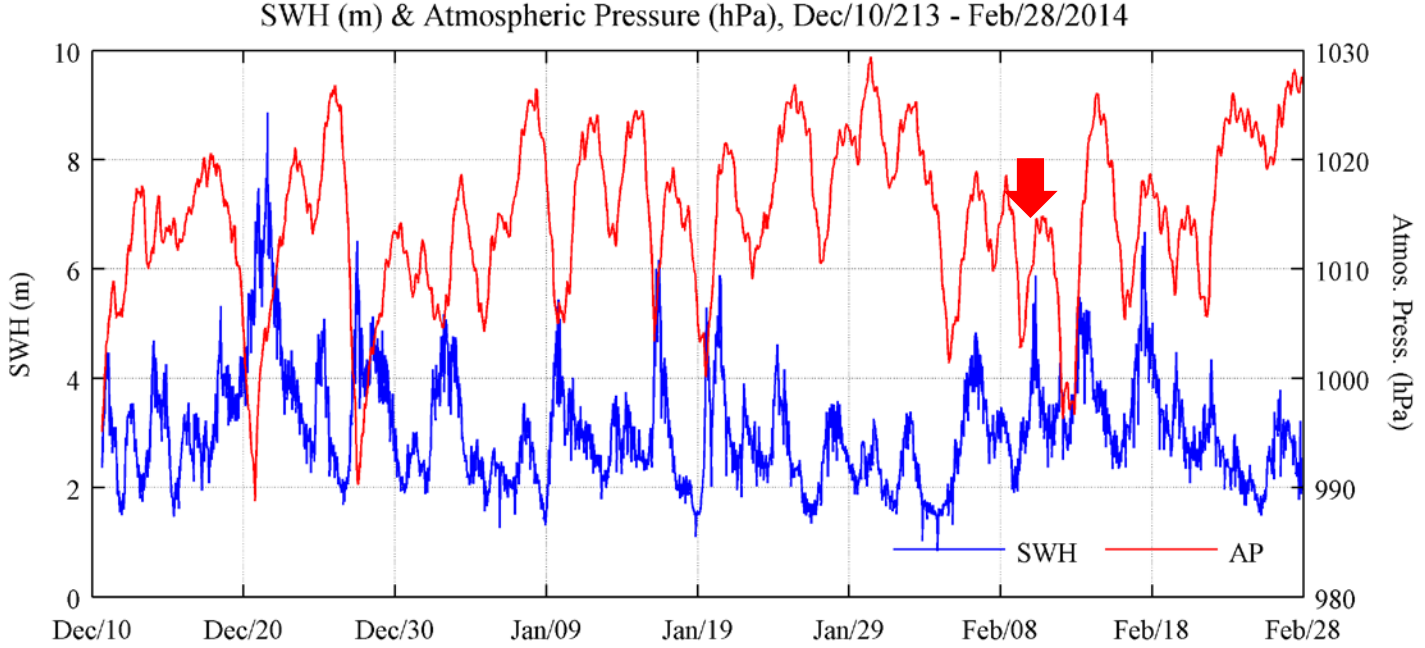


9日(日)網走で流氷接岸初日

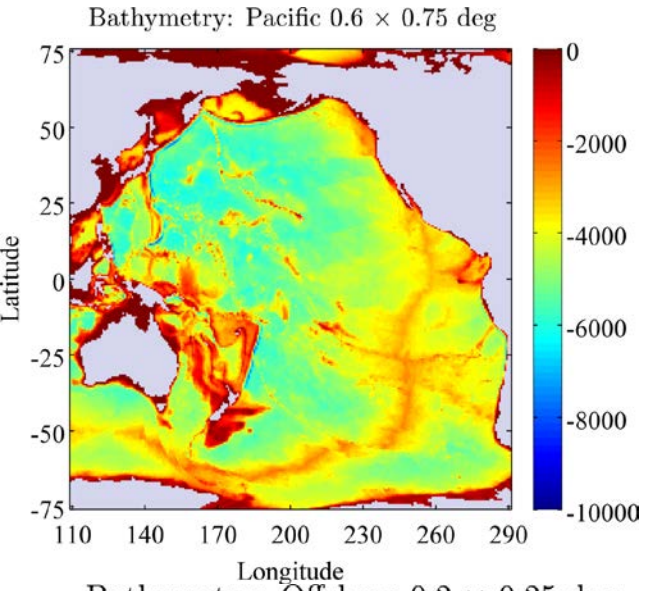


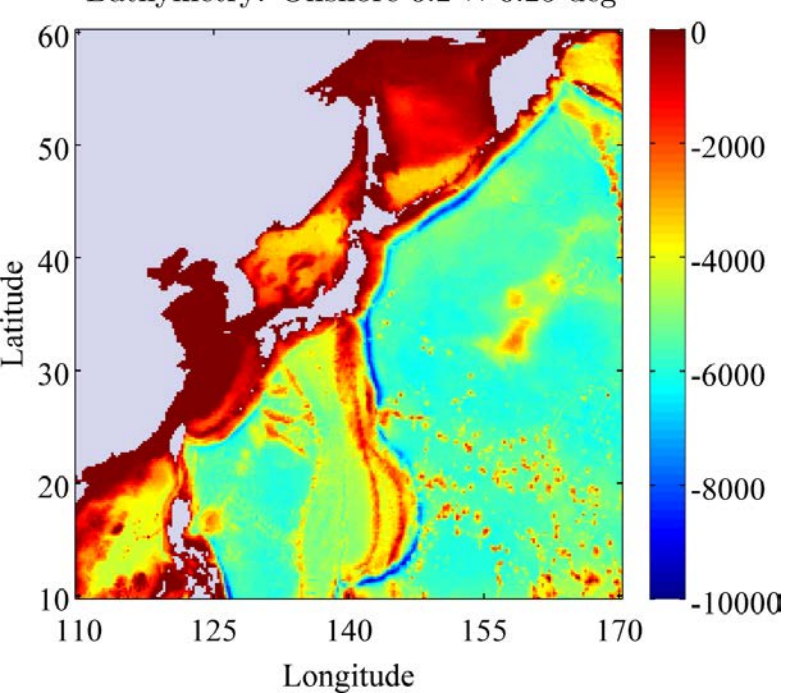
10日(月)石垣市でサクラ満開

と北海
り曇り
高気温
ヒカン



Wave – Current interaction





WAVEWATCH III (ver. 4.18)

One-way nested model

Pacific (0.6˚x0.75˚) -> Offshore (0.2˚x0.25˚)

NEDO potential project

Period: Jul. 2013 – Jun. 2014

Wind: NCEP CFSR

Current: no-current, JCOPE2 (and AVISO)

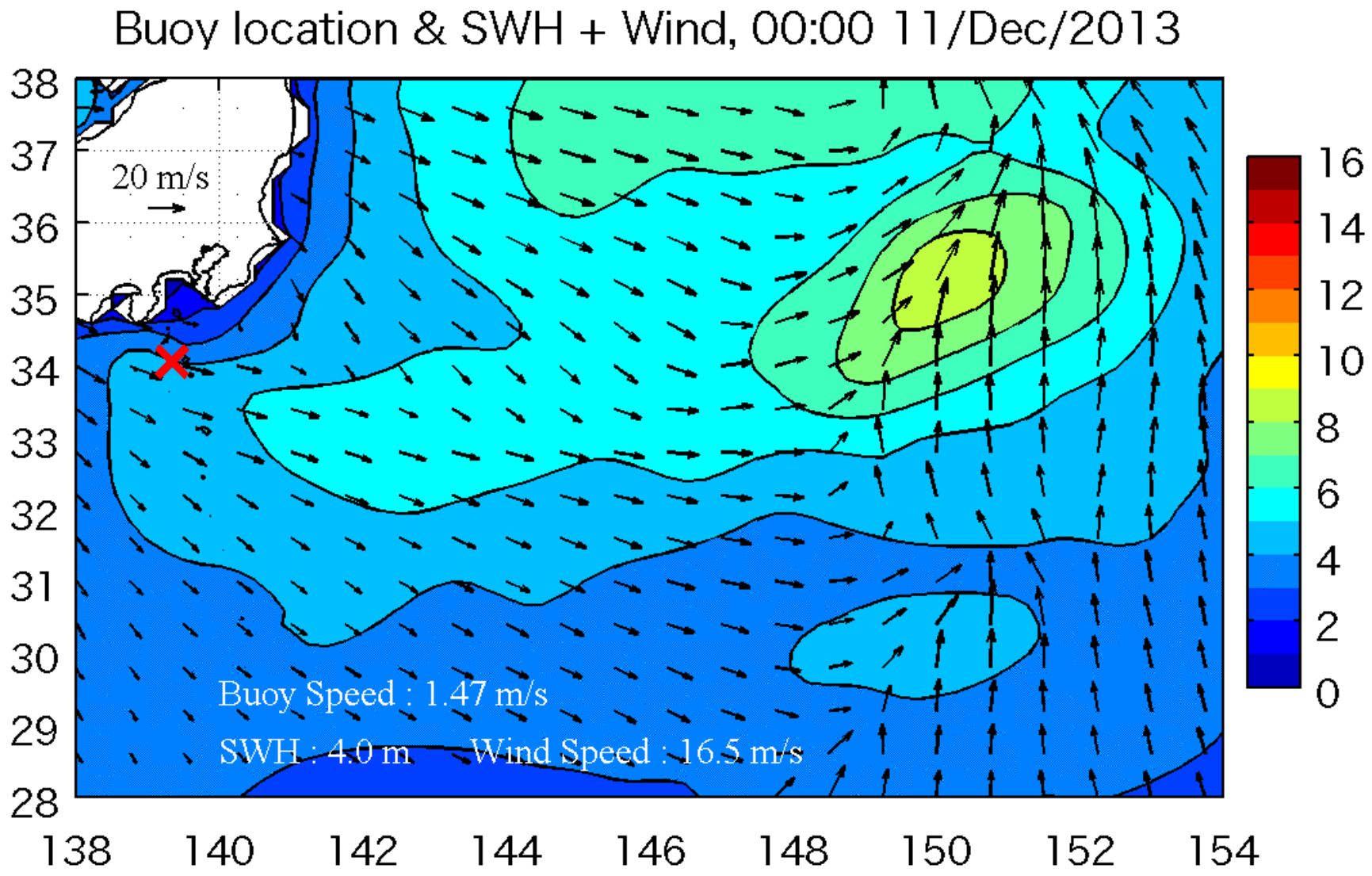
$$\frac{\partial N}{\partial t} + \nabla_x \cdot \dot{\mathbf{x}} N + \frac{\partial}{\partial k}\dot{k} N + \frac{\partial}{\partial \theta}\dot{\theta} N = \frac{S}{\sigma},$$

$$\dot{\mathbf{x}} = \mathbf{c}_g + \mathbf{U},$$

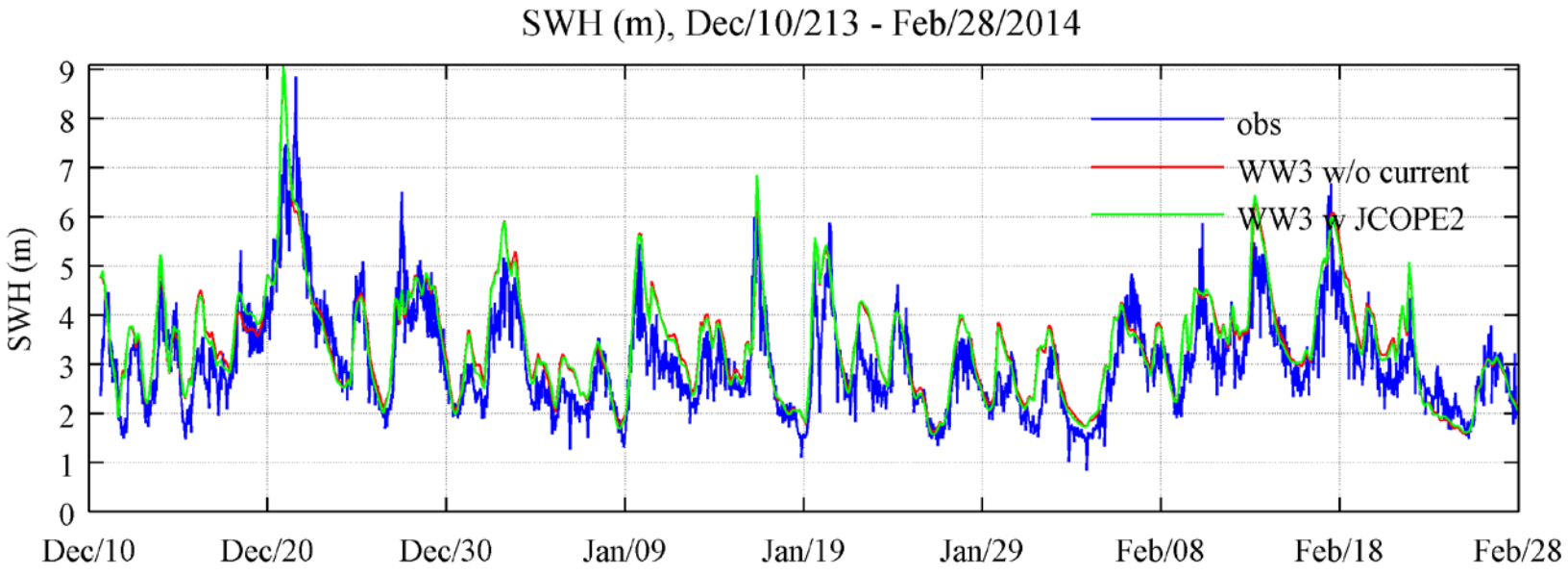
$$\dot{k} = -\frac{\partial \sigma}{\partial d}\frac{\partial d}{\partial s} - \mathbf{k} \cdot \frac{\partial \mathbf{U}}{\partial s},$$

$$\dot{\theta} = -\frac{1}{k}\left[\frac{\partial \sigma}{\partial d}\frac{\partial d}{\partial m} - \mathbf{k} \cdot \frac{\partial \mathbf{U}}{\partial m}\right],$$

Animation: Bouy location, simulated SWH & Wind

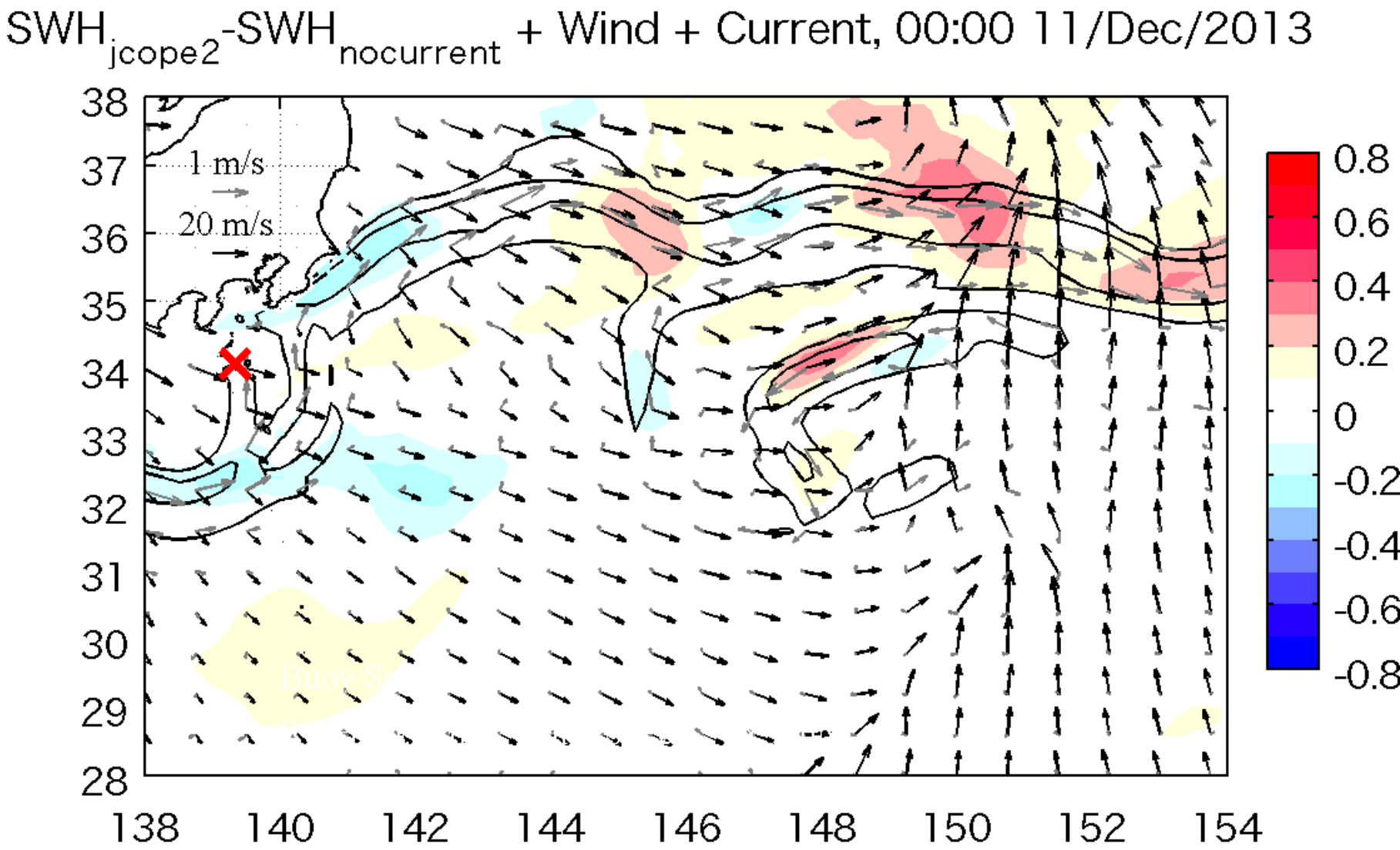


Impact of currents on simualted SWH along the buoy trajectory



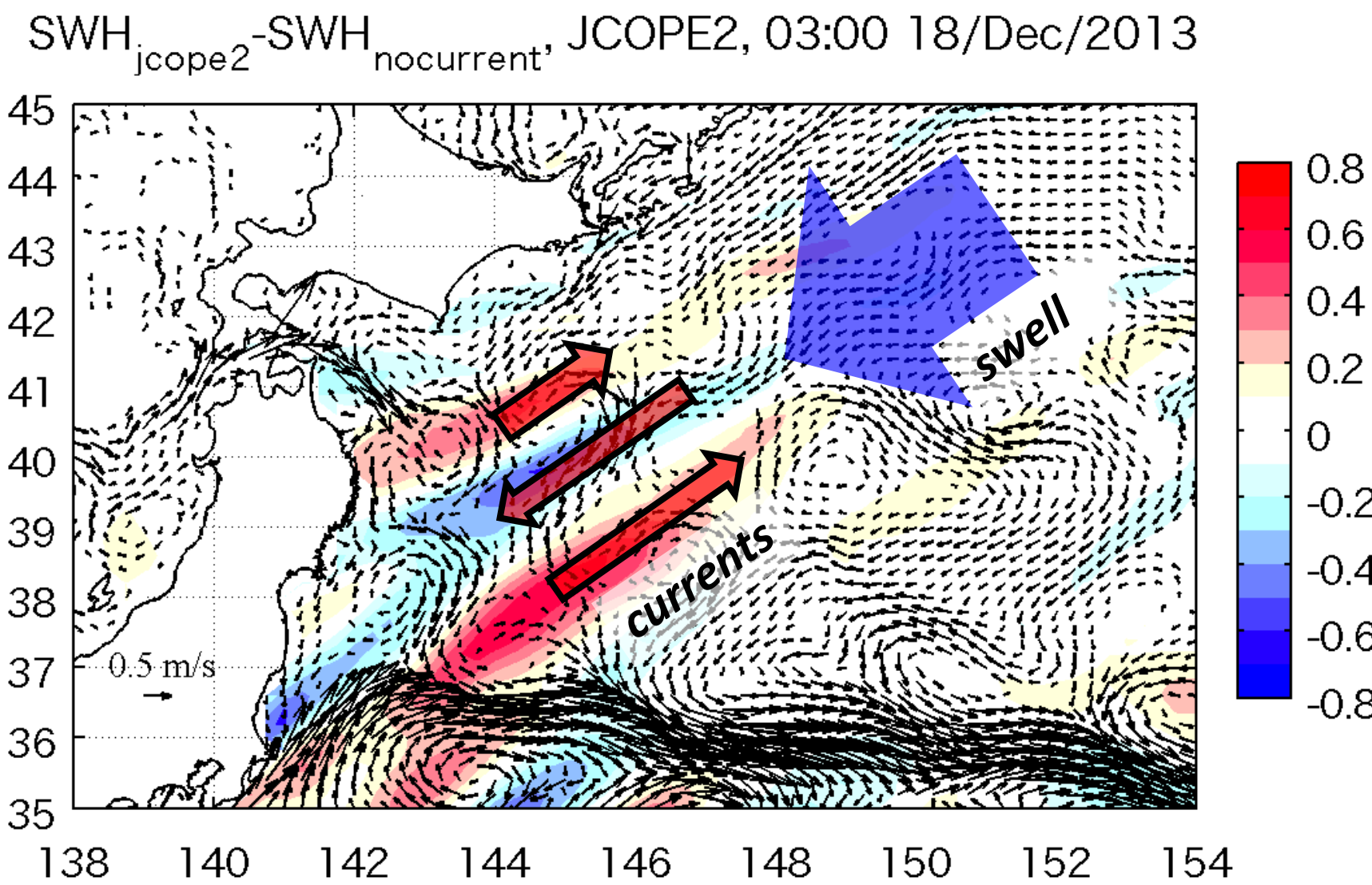
Error index	No current	JCOPE2	AVISO
Bias (m)	0.37	0.34	
Unbiased RMSE (m)	0.56	0.55	
C.C.	0.86	0.87	

Basically, ocean currents has very small impact on error indexes.



Animation, SWH_{jcope2} - $SWH_{nocurrent}$ (color)

The buoy doesn't move areas where waves are largely modulated by currents.



Modulation of swell due to the Oyashio and meso-scale eddies.

-> Oyashio Current is also important for simulating waves east of Japan.

Summary

The GPS wave buoy data during the drifting event was analyzed.

- One of motivation is to make a description of the data for data release

Following things were explained.

i. Buoy trajectory

Buoy trajectory was categorized into four different groups based on the buoy location.

- Inshore area of the Kuroshio, Kuroshio Extension, Southern edge of the KE, and Southern Recirclation area of the KE

ii. Wave characteristics and related weather condition

Northerly wind on the western side of low pressure over the east of Japan is the dominant forcing of the observed waves.

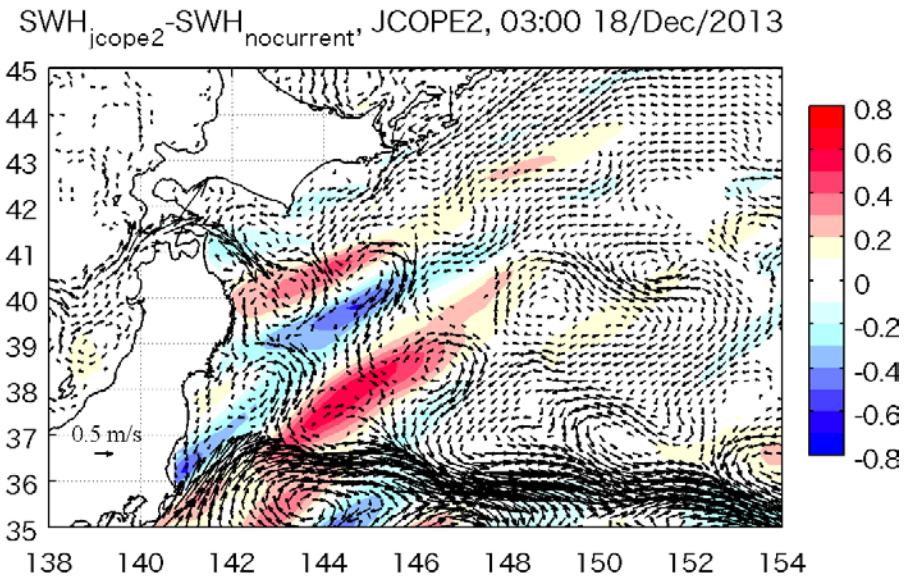
iii. Wave-current interaction

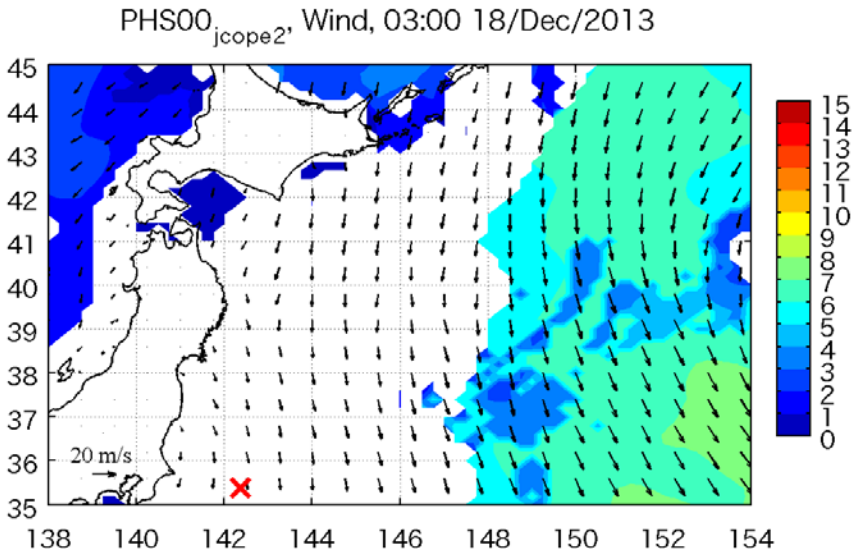
Wave-current interaction is an important factor for simulating the waves around KE region. But effect of wave-current interaction on the simulated along-trajectory SWH is very small.

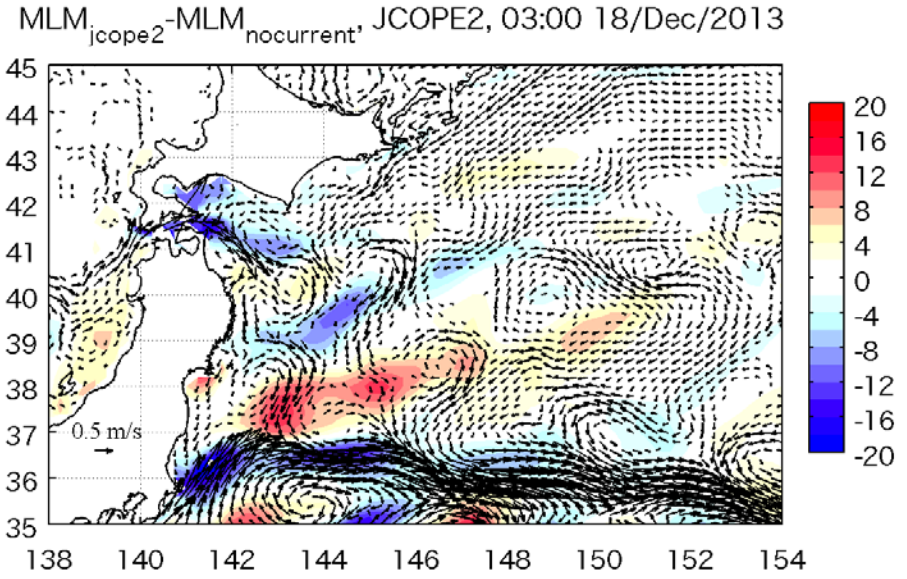
Acknolegement

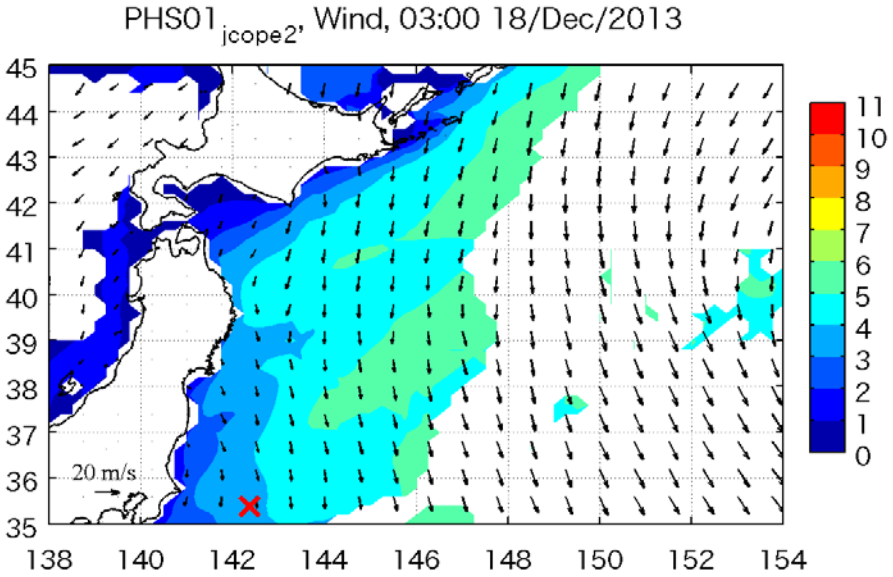
This work was supported by

- **Mitsui Engineering and Shipbuilding Company**
- **Researchers and crew of Hakuho-maru**









Modulation of swell due to the Oyashio, Kuroshio Extension, and eddies